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A GRAPHIC STUDY OF TREMOR

BY

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(FROM THE PHILADELPHIA ORTHOPEDIC HOSPITAL AND INFIRMARY FOR NERVOUS DISEASES)

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A GRAPHIC STUDY OF TREMOR.*

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Plates XXIII–XXX.

The work embodied in this report was undertaken at the suggestion of Dr. S. Weir Mitchell, whose hearty co-operation and material aid it further had throughout. Among the objects of the investigation was the determination (1) whether or not a demonstrable tremor exists in healthy individuals; (2) whether or not any relation or gradation exists among various kinds of tremor; and (3) whether or not various forms of disease present, as to their tremor, distinguishing characteristics.

The subject of tremor has always attracted considerable attention, especially in a clinical way, and a number of interesting graphic studies have been made. Most of these observations, however, have dealt only with the tremor associated with diseased states, particularly with regard to the form and frequency of movement and the influence of rest and action, or passivity and activity. With the exception of Peterson,† no one has, so far as I am aware, undertaken an analysis of the character of the movements, and it was hoped that this object might be fulfilled in the present study; but our efforts in this direction have not been entirely successful.

The first difficulty encountered consisted in the lack of a suitable apparatus, as none of those previously described appeared sufficient or available for the purposes of the investigation. A number of investigators (Debove and Boudet,‡ Marie,§ Horsley and Schaefer,|| Dutil,¶

* Read before the College of Physicians of Philadelphia, November 5, 1896.

† *Journal of Nervous and Mental Diseases*, February, 1889; *New York Medical Journal*, Oct. 11, 1890, p. 393.

‡ *Arch. de Neurologie*, i, 191, 1880–1.

§ Thèse de Paris, 1883.

|| *Journal of Physiology*, 1886, pp. 96, 111.

¶ Thèse de Paris, 1891.

Fernet* and Filliatre†) have used two tambours, connected by tubing which transmits to the second the movement imparted to the first. Others‡ have substituted a rubber ball for the first tambour. Still others§ used various forms of sphygmographs. Von Kries|| preferred a steel spring to which a glass style was attached. Ughetti¶ employed an apparatus resembling the scales of commerce. This consisted of a vertical arm connected with a horizontal arm carrying a stylus. The vertical arm was supported by two springs and was provided with a toothed dial, on the face of which a needle registered the amount of pressure employed. The elaborate apparatus employed by Warner** permitted only the enumeration of various kinds of movements of the hand and its component parts. It consisted of (1) a series of rubber tubes to be attached to the hand, one tube to each finger or moving part; these were connected, by means of pieces of thin conducting tubing, with a set of tambours; (2) a frame supporting the recording tambours and electric signals; (3) an electric contact-making tambour, a modification of the Marey tambour, adapted to the purpose of actuating, and (4) an electric counter.

On looking over the ground, the conclusion was reached that the most suitable, as well as the most simple, apparatus would be one based upon the principles governing the construction of instruments already in use for the graphic study of various physiological phenomena, *e. g.* the pulse beat, the heart beat or the respiratory movements. The accompanying illustration (p. 303) and description represent the instrument devised for the purposes of this study and which is to all intents and objects nothing more than an inverted sphygmograph upon a large scale. It consists of a tripod (A) about four inches high, mounted upon a base of iron (a), to give it stability,

* Des Tremblements. Thèse de Paris, 1892.

† *Arch. de Neurologie*, September, 1894, p. 161.

‡ Marie, loc. cit.; Wolfenden and Williams, *British Med. Journal*, May 19. 1888.

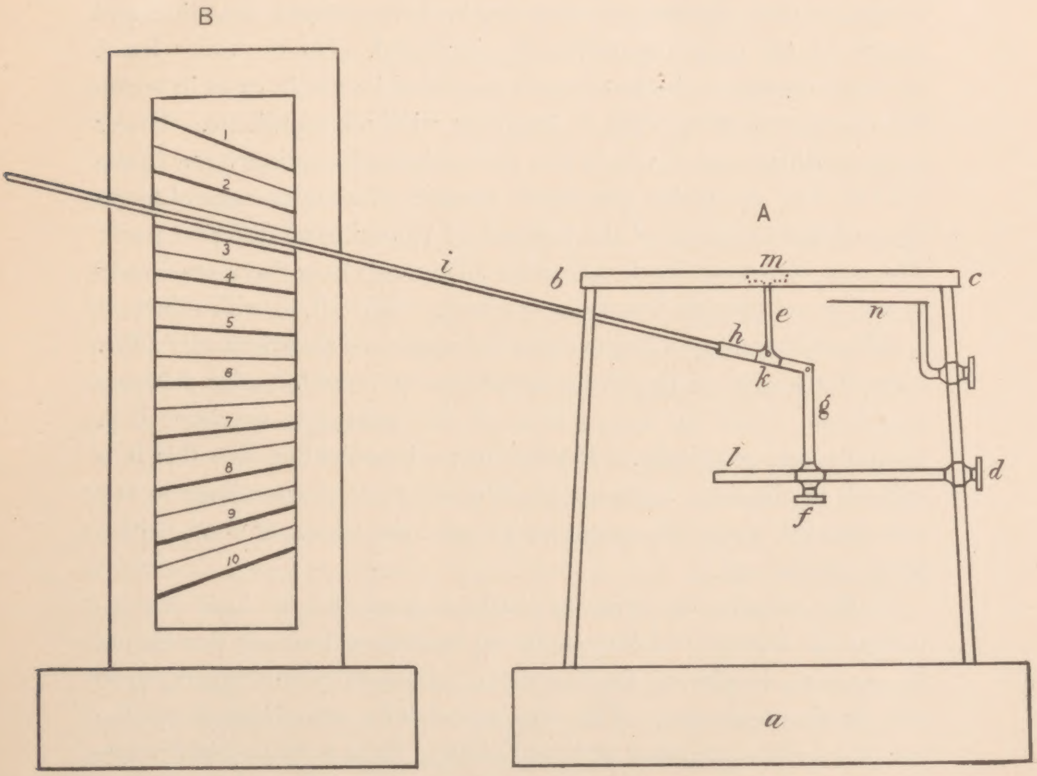
§ Grashey, *Arch. f. Psychiatrie*, xvi, p. 857, 1885; Huber, Virchow's *Archiv*, cviii, p. 45; Peterson, *Journal of Nervous and Mental Diseases*, February, 1889, p. 99; Dana, *Medical News*, December 17, 1892.

|| *Arch. f. Physiologie*, 1886.

¶ *Rivista sperimentale di freniatria*, xix, fasc. 2, 3; *Rev. Internat. de Bibliogr. Méd., Pharm. et Vetér.*, 1893, No. 24, p. 451.

** *Journal of Physiology*, iv, p. 160.

and surmounted by a metallic ring (*bc*) four inches in diameter, over which is stretched an elastic membrane. Attached to one of the legs of the tripod, by means of a sliding ring and clamp-screw (*d*), is a horizontal metal bar (*l*) about two and one-half inches long, which can be raised or depressed. This rod in turn carries, also by means of a sliding ring and clamp-screw (*f*), a short vertical rod (*g*) an inch in length, which can be slid forward and backward. The upper



Tremograph and Pressure Scale. Diagrammatic, one-half actual size.

extremity of this vertical rod is bifurcated for the reception of a light bar (*h*), so pivoted upon either branch as to be capable of movement at its free extremity in a vertical plane, and with which the inscribing or registering needle (*i*) is connected through the intermediation of a prolongation of aluminum. Attached to this bar by means of a sliding band (*k*) is a slender rod (*e*) an inch long, jointed below to the sliding band and above to a small flat button (*m*), about $\frac{3}{8}$ of an inch in

diameter, which is glued to the under surface of the elastic diaphragm.*

It will be seen that every movement imparted, for instance by the fingers, to the elastic membrane will be transmitted to the registering needle, and in magnified degree, in inverse proportion to the length of the proximal arm of the lever formed by the arrangement of the constituent parts of the instrument. By this means it has been possible to demonstrate movements that would have escaped detection and record by the apparatus ordinarily employed. On the other hand, the sensitiveness of the instrument precluded its use in cases in which the movements were wide in range or wildly incoordinate. Under these conditions resort was had to the tambours in ordinary use (Plate XXIII, Fig. 2), which permitted, further, of simultaneous observations of the two sides of the body or of two or more different parts. The new apparatus, while possessing advantages over those previously in use, is not entirely free from objection. With it, as with others, it is difficult, if at all possible, to make the conditions always exactly alike. Thus the tension of the elastic membrane is variable under differing conditions; while the co-operation of the patient is required, both mentally and physically. Besides, in an investigation like this it is difficult to eliminate extraneous influences, such as are related to rest and activity, sleep, the emotions, hunger, the taking of food, stimulants, tobacco, etc.

In the endeavor to obtain as nearly as possible some basis of comparison, an attempt was made to fix the amount of pressure that should be exercised in placing the tremulous part, usually the fingers, upon the elastic diaphragm. This was successfully accomplished by the use of a scale constituted of lines radiating from a centre, which corresponded to the fulcrum of the lever contained within the instrument (*B*, p. 303). This was mounted by the side of the needle, and as a given weight was placed upon the diaphragm of the apparatus, the level to which the needle descended was noted, and for the individual observation represented a known amount of pressure.

* For the construction of the instrument I am indebted to Mr. F. F. Metzger, of Philadelphia. The photographs of the apparatus were kindly made by my friend, Dr. H. P. Boyer.

To distinguish our apparatus we have designated it a "tremograph," and the tracings secured with its aid, "tremograms."

The experiments were ordinarily conducted by having the subject place the fingers, especially the index, middle and ring fingers, upon the diaphragm and exercise a measured amount of pressure, one, two, three or four ounces, as the case might be. By means of a plate (*n*, p. 303), fastened beneath the membrane to one of the legs of the tripod, it was possible to have the subject approximate the fingers, above with the thumb, below in a prehensile attitude, without, however, bringing them in contact, and again with a measured amount of pressure. This attitude is not incomparable with that assumed, for instance, by the watchmaker in the execution of fine movements or by the surgeon in the performance of delicate operations.

In using the tambours, one of these (the transmitter) either was placed upon the lap of the subject, with the fingers gently applied, or was held between the partially flexed fingers and thumb, while the other (the receiver), through the intermediation of the style, was brought in relation with the smoked paper mounted upon the revolving kymographic apparatus.

In the course of this study upward of 1100 individual observations were made on more than 100 different persons. Nearly all of the subjects were derived from the Infirmary for Nervous Diseases—physicians, surgeons, nurses, patients—the last almost exclusively from the large clinical service of the Infirmary, generously placed at my disposal by the attending physicians, Drs. S. Weir Mitchell, Wharton Sinkler and Morris J. Lewis. A number of cases came from the private practice of Dr. Mitchell, and several professional colleagues kindly volunteered their services for the study of the tremor of the healthy. Watchmakers were studied through the courtesy of Messrs. Bailey, Banks and Biddle; and a number of men from the Old Men's Home afforded material for the study of the tremor of the aged.

While the results reached are not entirely satisfactory, in consequence partly of the inherent difficulties of the investigation and partly of mechanical deficiencies, they have still developed a number of interesting facts.

It was definitely determined that a tremor could be demonstrated

in healthy persons. This was to have been expected, as every muscular movement is made up of a series of alternate contractions and relaxations, occurring ordinarily with such frequency as to escape detection with the unaided eye.* As the frequency of contraction and relaxation diminishes, the tremor increases. The occurrence of tremor in healthy persons is further supported by the testimony of other observers.†

In a general way it was found that the frequency of movement bore an inverse relation to its extent, that is, the wider the range, the smaller the number of movements. This observation is of the utmost significance, as it largely negatives the likelihood of distinctiveness for the tremor of any disease, the extent of movement under any circumstances being extremely variable and influenced by various temporal conditions. Corroboration of this attitude is found in the statement of Fernet,‡ that the more frequent the muscular contraction occurring spontaneously or induced electrically, the less pronounced the tremor. Further confirmation of this position is found in the statement of Huber,§ that the rate of contraction varies in different muscles of the same individual, and in the same muscles on different days. Gowers|| also found considerable variations in the movements of different parts of the body of the same individual. Peterson¶ observed in cases of paralysis agitans that the movements were fewer in number as they were coarser, and that the rate of vibration differed in different parts of the body, and in the same part on different days.

Those acts were performed with the least tremulousness which the subject was mostly in the habit of executing (see Tracings 1, 2, 3, 4,

* If any one have doubts upon this subject, let him attempt to hold steadily in his hand a glass of water or other fluid and view the surface. In this connection I am reminded of an incident related of a skilled surgeon, noted especially for his steadiness of hand, who when spoken to upon the subject by a junior colleague was unwilling to admit that his hand shook. On placing, however, the fingers in a vessel of water, the rippling disturbance of its surface at once proved the contention of the younger man. If a photographic reproduction of the waves of motion generated under these conditions could be made, it might prove serviceable in such a study as has here been undertaken.

† Debove and Boudet, loc. cit.; Horsley and Schaefer, loc. cit.; Beaunis, quoted by Wolfenden and Williams, loc. cit.

‡ Loc. cit.

§ Loc. cit.

|| Gowers, Diseases of the Nervous System, 1888, p. 1000.

¶ Peterson, *New York Med. Journal*, October 11, 1890, p. 393.

Plates XXIV–XXVII). Thus the watchmaker, the laryngologist and the eye surgeon displayed less movement in the exercise of less pressure than in that of more, while those unaccustomed to delicate manipulations displayed more movement under the same conditions, and less under the reverse. Ughetti* records, on the contrary, that in his observations the amplitude of the oscillations increased with the amount of pressure. Whilst the tremor of most morbid states is increased by intended movement, and that of the healthy state is probably induced by the same influence, it seems that in the trained hand the movement may, under these conditions, be reduced to a minimum, as a result of extreme delicacy of co-ordinative adjustment, either natural or acquired, and it may further be that some sense of security or guidance is derived from the performance of a well-defined and accustomed voluntary movement. The tremor was in general not appreciably influenced by the slight variations in pressure made. Tracings 1, 2, 3 and 4, Plates XXIV–XXVII, appear exceptional, in consequence of modifications dependent upon occupation and habitual movements.

The extent of movement was ordinarily smaller when the thumb and fingers were approximated in the attitude of prehension than when the fingers alone were applied to the tremograph (compare Tracings 2 and 4 with Tracings 1 and 3). This is probably due to the sense of support afforded by the former attitude and to the inhibitory influence of a well-defined voluntary act. In general, also, the number of movements in the same case, at the same observation, was smaller as registered with the aid of the tambours than when shown by the tremograph. This is probably owing to the greater delicacy of the latter, as the finer movements are lost in transmission through the tambours. The mental attitude of the subject seemed to have an appreciable influence upon the tremogram, the more intelligent and the more careful displaying greater movement under the same conditions than the unintelligent and the indifferent. Familiarity with the necessary manipulations on the part of the subject also brought with it greater steadiness.

The greatest frequency of movement computable was 10.7 per second, and was observed in a healthy individual and also in a hemi-

* Ughetti, loc. cit.

plegic; the smallest was 3, observed in a case of posterior spinal sclerosis. The general average of movement among all of the observations was 6.7. There was a good deal of uniformity of average under varying conditions when large numbers of cases were studied. On the other hand, the differences were more conspicuous among individual cases.

In a number of conditions, and especially in cases of paralysis agitans and of the spinal scleroses, the movements of symmetrical parts of the two sides of the body seemed to be practically synchronous (even when differences in the range of movement existed), in so far as comparative observations could be made (see Tracing 5, Plate XXVIII). When any difference existed between the movements of the two sides, it was slight and not constant.

Most of the movements displayed a want of regularity or rhythm. This was especially noticeable in the slighter and ill-defined movements, as those of health. Those of paralysis agitans particularly, as well as those in a case of diffuse sclerosis suggestive of paralysis agitans, displayed as a rule a tendency to regularity and rhythm. The occurrence of secondary or dicrotic waves, and even of tertiary waves, was often noted in tracings from cases of paralysis agitans (see Tracing 6, Plate XXIX). It was also observed in two cases of multiple sclerosis, one of which was suggestive in some respects of paralysis agitans. This peculiarity, which has also been noted by Wolfenden and Williams* and by Peterson,† will account for the wide variations noted in some cases. Of course the number of movements is greater when these secondary waves appear and less when they are suppressed. In this connection Wolfenden and Williams go so far as to contend that the special characteristics that distinguish clinically the various forms of tremor are to be traced to two causes: (1) an exaggeration of the amplitude of the normal vibration; and (2) the fusion of vibrations, which has the effect of producing a relatively slow tremor, generally of a rate corresponding to half that of the normal vibration.

It was hoped, among other things, that this study would aid in the differentiation between multiple sclerosis and paralysis agitans, but in this respect we were disappointed. Often easy, the diagnosis between these two conditions is at times exceedingly difficult. There

* Loc. cit.

† Loc. cit.

is reason for believing that the two affections are not unrelated both clinically and pathologically. At any rate it is probable that too much importance has been attached to the influence of rest and of voluntary effort respectively upon the tremor in the differentiation. In this connection it must not be forgotten that unequivocal cases of paralysis agitans may be unattended with appreciable tremor, either on account of its real absence or because of its concealment by the rigidity so often present.

We have been able to demonstrate graphically a clinical observation made by Dr. S. Weir Mitchell, that in cases of paralysis agitans, forcible extension of a finger of the shaking hand may temporarily restrain the movement of the hand (see Tracing 7, Plate XXX). That this interference is not merely mechanical is shown by the fact that the tremor soon recommences, even though the extension of the finger be maintained. Besides, similar restraint was sometimes observed when a finger of the opposite hand was thus extended. Some slight inhibition was at times induced by an effort of the will. Following the reduction in range of movement under these circumstances, there was usually an increase in the frequency. Closure of the eyes and of the opposite hand and the prick of a pin seemed to exercise only a transient disturbing influence, though occasionally an inhibiting effect was appreciable. In a case of choreal tremor, application of an Esmarch bandage to the arm was attended with a reduction in the range and rate of movement in the corresponding hand.

I present herewith a summary of the results of our study (Table A, p. 311) and append also a tabulation from various sources of those obtained by previous investigators in the study of tremor (Table B, p. 312). These tables show the wide variations of movement under all conditions, and strengthen the opinion already expressed, that special forms of tremor are not characterized by special frequency of movement. Indeed, it is probable that they present as well no other absolutely distinguishing feature.

CONCLUSIONS.

From our observations I think the following propositions are justified:

(1) All muscular movements are made up of a series of elementary

contractions and relaxations in alternation, which may be appreciable as tremor in conditions of both health and disease.

(2) The differences between different tremors are of degree rather than of kind, *i. e.* no one form of tremor is distinctive of any one disease or group of diseases.

(3) No definite relation exists between one form of tremor and any other.

(4) The frequency of movement is in inverse ratio to the amplitude and *vice versâ*.

(5) Habitual movements are performed with greater freedom from tremor than unusual movements.

(6) There is no material difference between the movements of the two sides of the body, except as related to Proposition (5).

DESCRIPTION OF PLATES XXIV–XXX.

See description in text, pp. 306-309.

(The tracings are to be read from left to right.)

Tracing 1 (tremograms).—From a watchmaker in health, 44 years old. *a*, the tremor attending delicate application with the right hand of a pair of forceps to the elastic diaphragm; *b*, the tremor from pressure of 1 oz. with the free fingers; *c*, that from a pressure of 2 oz.; *d*, that from a pressure of 4 oz. The broken straight lines represent time in seconds. The range of movement is greater as the pressure increases.

Tracing 2.—The curves are from the same case as Tracing 1 and were made under the same conditions, except that the fingers, above on the diaphragm, were approximated toward the thumb, below on the metallic plate, in the attitude of prehension.

The range of movement is distinctly less throughout than in Tracing 1.

Tracings 3 and 4 represent the same conditions as Tracings 1 and 2 respectively, except that the fingers of the left hand instead of the right were employed. The range of movement is in each instance greater with the left hand. The same relation as to range of movement holds between Tracings 3 and 4 as between Tracings 1 and 2.

Tracing 5 (two tambours).—From a case of paralysis agitans. Shows synchronism. The upper curve represents the tremor of the left hand, the lower that of the right. The broken straight line represents time in seconds.

Tracing 6 (two tambours).—From a case of paralysis agitans, in which the tremor preponderates upon one side. Shows dicrotism. The upper curve represents the tremor of the right hand; the lower, that of the left. The broken straight line represents time in seconds.

Tracing 7 (two tambours).—From a case of paralysis agitans. Shows the restraining influence of extension of the little finger of the tremulous member.

TABLE A.—Summary.

	Tremograph.						Tambours.					
	Right.			Left.			Right.			Left.		
	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
Health	10.0	4.5	7.0	10.7	4.0	6.7	..	..	..	..	..	..
Senility	8.5	5.2	6.8	8.0	5.2	6.6	..	..	..	..	..	..
Paralysis Agitans	8.9	5.2	6.3	8.5	5.0	6.3	7.3	4.5	5.5	7.8	4.5	5.5
Multiple Sclerosis	8.5	7.3	7.5	9.3	6.1	7.3	7.6	4.5	6.4	8.0	4.0	6.0
Diffuse Sclerosis	7.0	6.0	6.7	7.0	6.0	6.6	..	..	..	..	..	..
Posterior Sclerosis	5.0	3.6	4.4	5.3	3.0	4.4	..	..	..	..	..	..
Postero-Lateral Sclerosis	..	..	6.0	..	..	6.0	..	..	..	..	..	..
Hysteria	10.0	5.4	8.0	9.5	4.9	7.3	7.5	6.4	7.0	..	..	..
Neurasthenia	9.0	4.5	7.0	8.9	4.8	7.0	..	..	..	..	..	..
Exophthalmic Goitre	10.0	4.7	7.4	9.0	4.4	6.9	..	..	..	..	..	..
Writer's Neurosis	8.5	5.4	6.9	8.8	5.9	7.6	..	..	..	..	..	..
Melancholia	7.3	4.7	6.3	5.9	5.5	5.6	..	..	..	..	..	..
Right Hemiplegia	..	..	..	5.5	4.0	4.8	..	..	..	10.0	8.3	9.2
Left Hemiplegia	10.7	9.0	9.6	6.0	5.5	5.6	10.5	9.0	9.8	..	..	8.5
Chorea	5.1	5.0	5.0	..	..	5.0	..	..	3.9	4.0	3.6	3.8
Goitre	8.0	5.5	7.3	10.0	5.0	6.4	..	..	..	..	..	..
General Neuritis	7.5	5.2	6.5	7.5	5.2	6.6	..	..	..	..	..	..
Chronic Alcoholism	9.0	8.0	8.5	8.5	8.0	8.3	..	..	..	..	..	..
Pendulum Tremor	..	..	..	..	..	..	..	..	..	6.2	5.8	6.1
Arsenical Poisoning	7.5	7.4	7.5	..	..	6.8	..	..	..	..	..	4.9
Torticollis	..	..	..	..	..	..	..	..	..	..	..	7.6

Head.	Max.	Min.	Aver.
Lateral.	4.6	3.3	4.4
Ant.-Post.	3.9	3.3	3.6

Head.	Max.	Min.	Mean.
	7.9	7.6	7.8

TABLE B.

	Health.	Senility.	Paralysis Agitans.	Multiple Sclerosis.	Diffuse Sclerosis.	Posterior Sclerosis.	Postero-Lateral Sclerosis.	Hysteria.	Neurasthenia.	Exophthalmic Goitre.	Writer's Neurosis.	Melancholia.	Right Hemiplegia.	Left Hemiplegia.	Chorea.	Goitre.	General Neuritis.	Chronic Alcoholism.
Dana	10.0	5.0	3.0–6.1	..	..	8.0–8.6	..	5.0	10.0	8.0–9.5	..	..	..	..	..	..	..	6.2
Peterson	..	..	3.5–5.6	4.6–6.3	..	..	..	7.6–7.8	7.4	8.7–12.0	..	..	..	..	..	..	..	8.5–11.0
Wolfenden and Williams	..	5.5	5.1	5.8	..	..	..	..	..	10.8–11.5	..	..	..	..	..	..	..	..
Dutil	..	4.0–5.5	5.0–6.0	4.0–5.5	..	..	..	5.5–7.5	..	8.0–9.5	..	..	..	..	..	..	..	8.0–9.0
Fernet	..	..	..	3.0–5.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Gowers	..	..	4.8–7.0	6.0–7.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Charcot	..	..	4.0–5.0	7.0–10.0	..	..	..	5.0–7.0	..	..	..	..	..	..	..	..	..	..
Marie	..	4.5–5.5	5.0	..	..	..	..	..	..	8.0–9.0	..	..	..	..	..	..	..	..
Péré	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Horsley	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Ewald	..	..	5.0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Grashey	..	..	4.1–5.3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Huber	..	..	3.4–5.6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Eshner	6.9	6.7	5.9	6.8	6.8	4.4	6.0	7.4	7.1	7.2	7.3	6.0	7.0	8.4	4.5	6.9	6.6	8.4

	Pendulum Tremor.	Arsenical Poisoning.	Torticollis.	Myelitis.	Progressive Muscular Atrophy.	Hemiplegia with Epilepsy.	Hemiplegia Embolism.	General Paresis.	Mercurial Poisoning.	Saturnine Poisoning	Delirium Tremens.	Lateral Sclerosis.	Hereditary Tremor.	Quinin.	Epilepsy.
Dana	..	..	..	5.0–6.0	5.0	4.8–5.0	10.0–12.0	..	..	..	..	6.0	8.0–9.0	10.0	8.5–8.8
Peterson	..	..	..	..	..	..	..	..	..	..	5.6 6.5	6.0	..	..	10.0
Wolfenden and Williams	..	..	..	..	..	..	..	..	..	..	..	5.5	..	..	..
Dutil	..	..	..	..	..	..	..	8.0–9.5	..	..	..	..	..	..	..
Fernet	..	..	..	..	..	..	..	..	5.0	6.0	..	..	..	..	..
Gowers	..	..	..	..	..	..	..	10.0–12.0	..	..	..	..	..	..	..
Charcot	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Marie	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Péré	..	..	..	..	..	..	..	..	..	..	..	..	..	..	10.0
Horsley	..	..	..	..	..	..	..	..	..	..	..	8.0–10.0	..	..	..
Ewald	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Grashey	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Huber	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Eshner	6.1	6.4	7.6	..	..	..	..	..	..	..	..	..	..	..	..

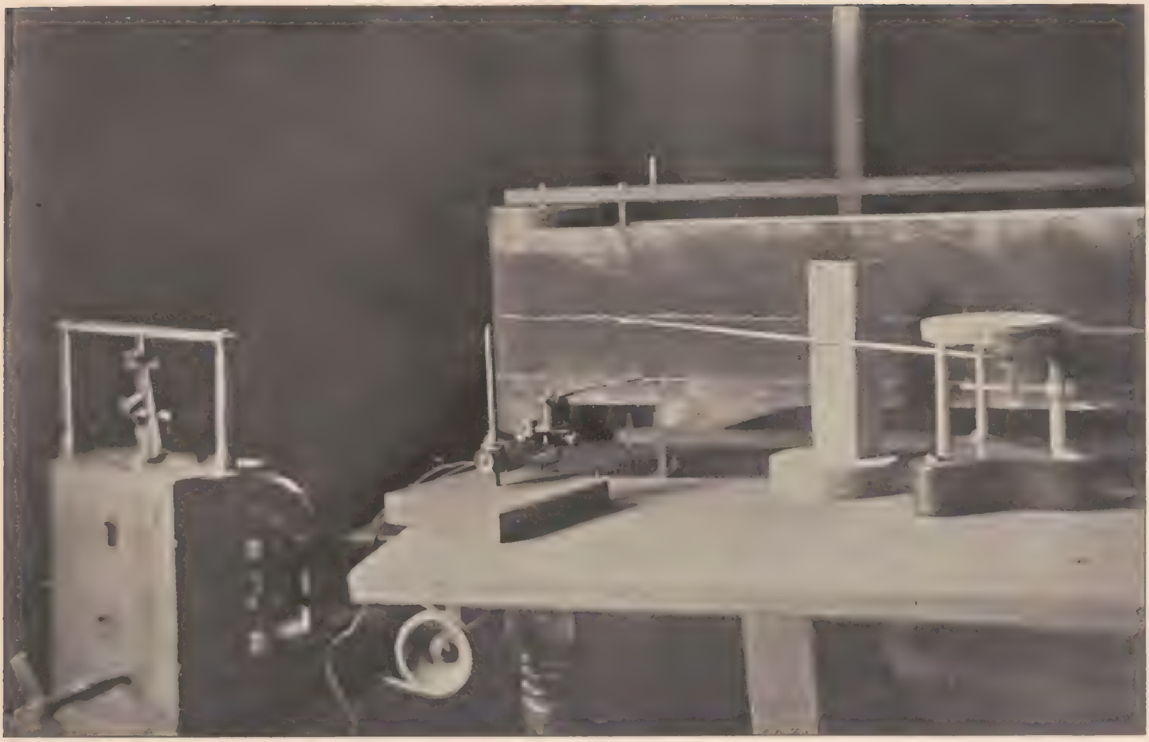
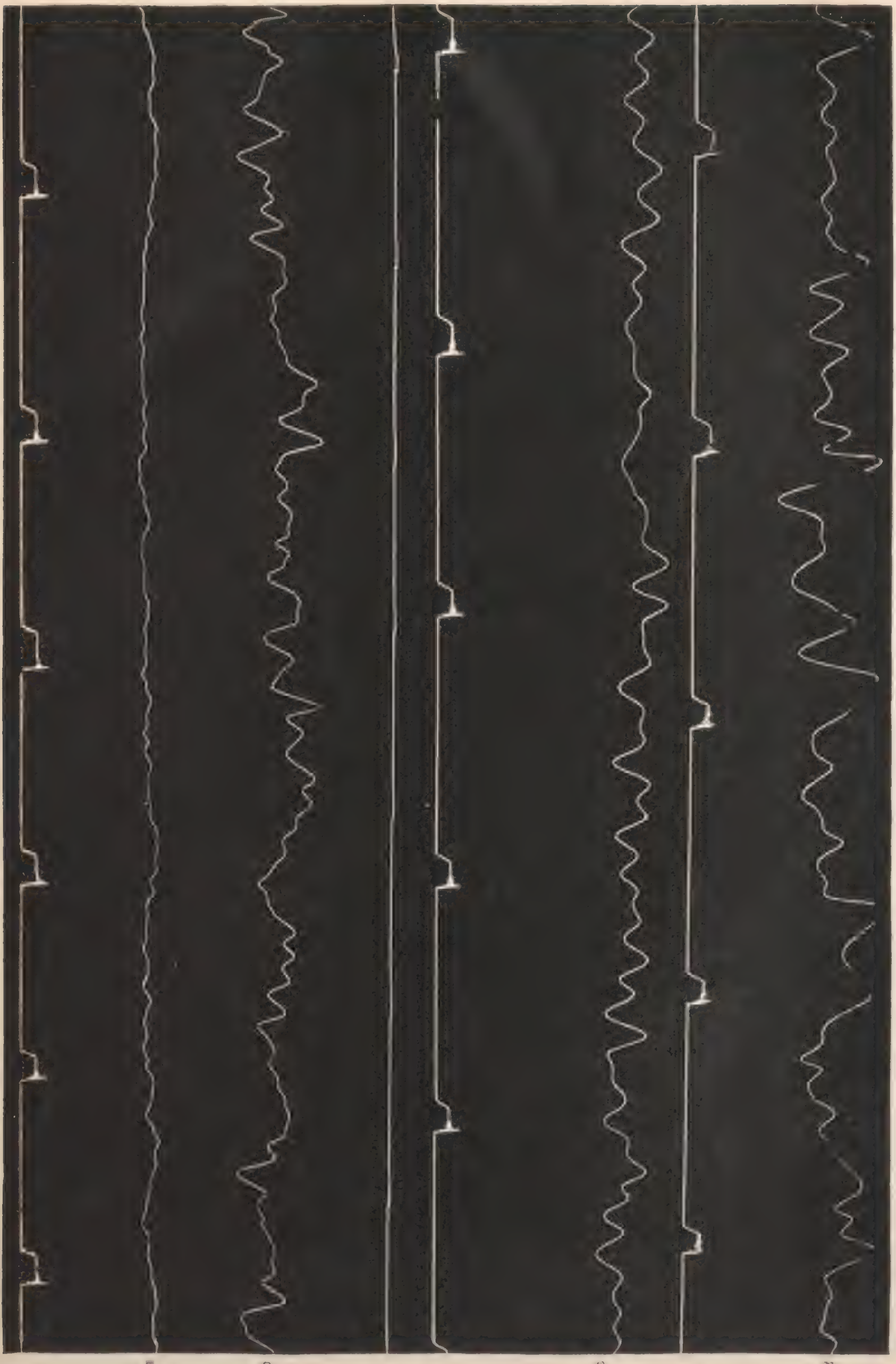


Fig. 1.

Tremograph with Kymographion.

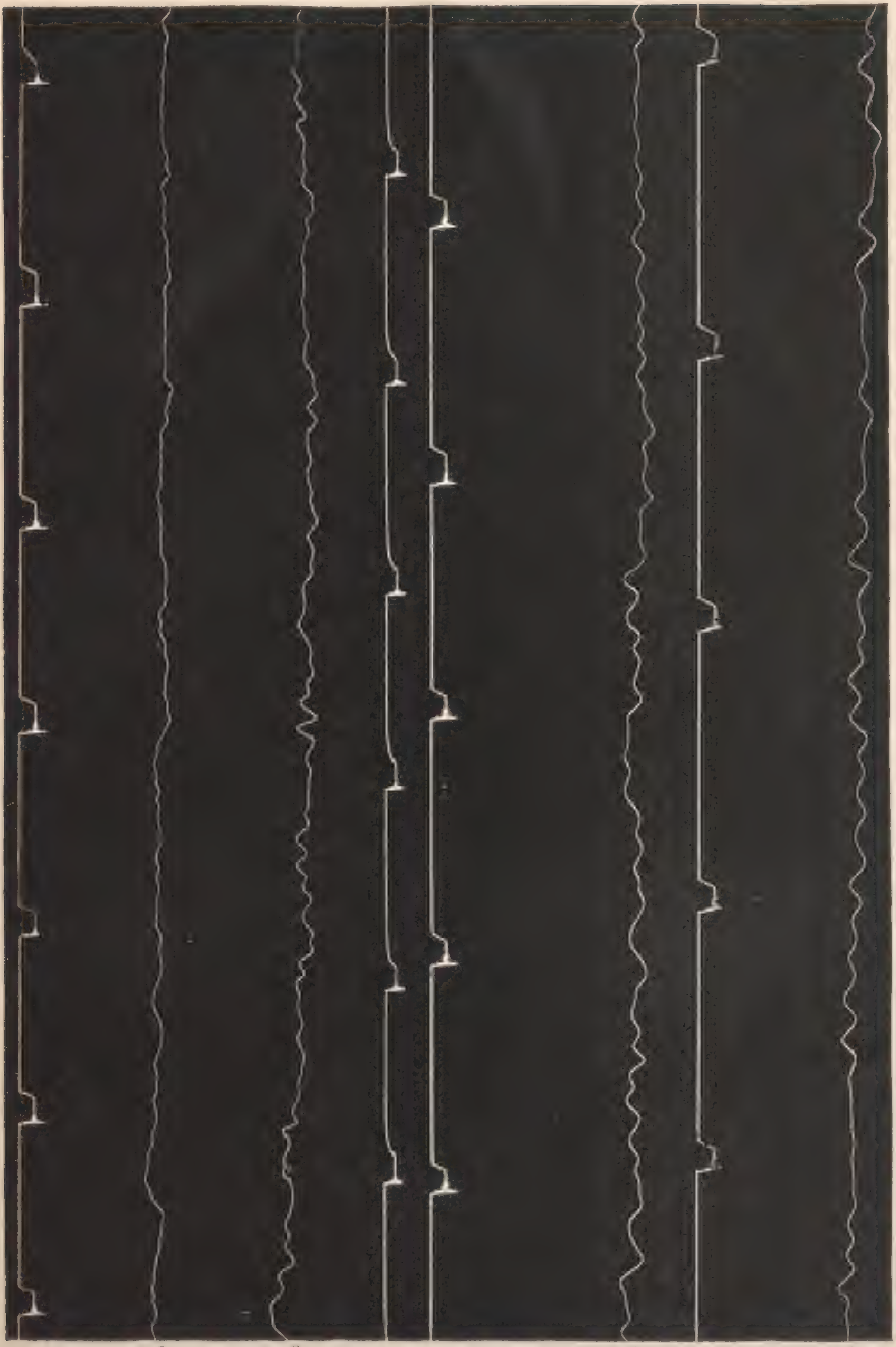
Fig. 2.

Tambours with Kymographion.



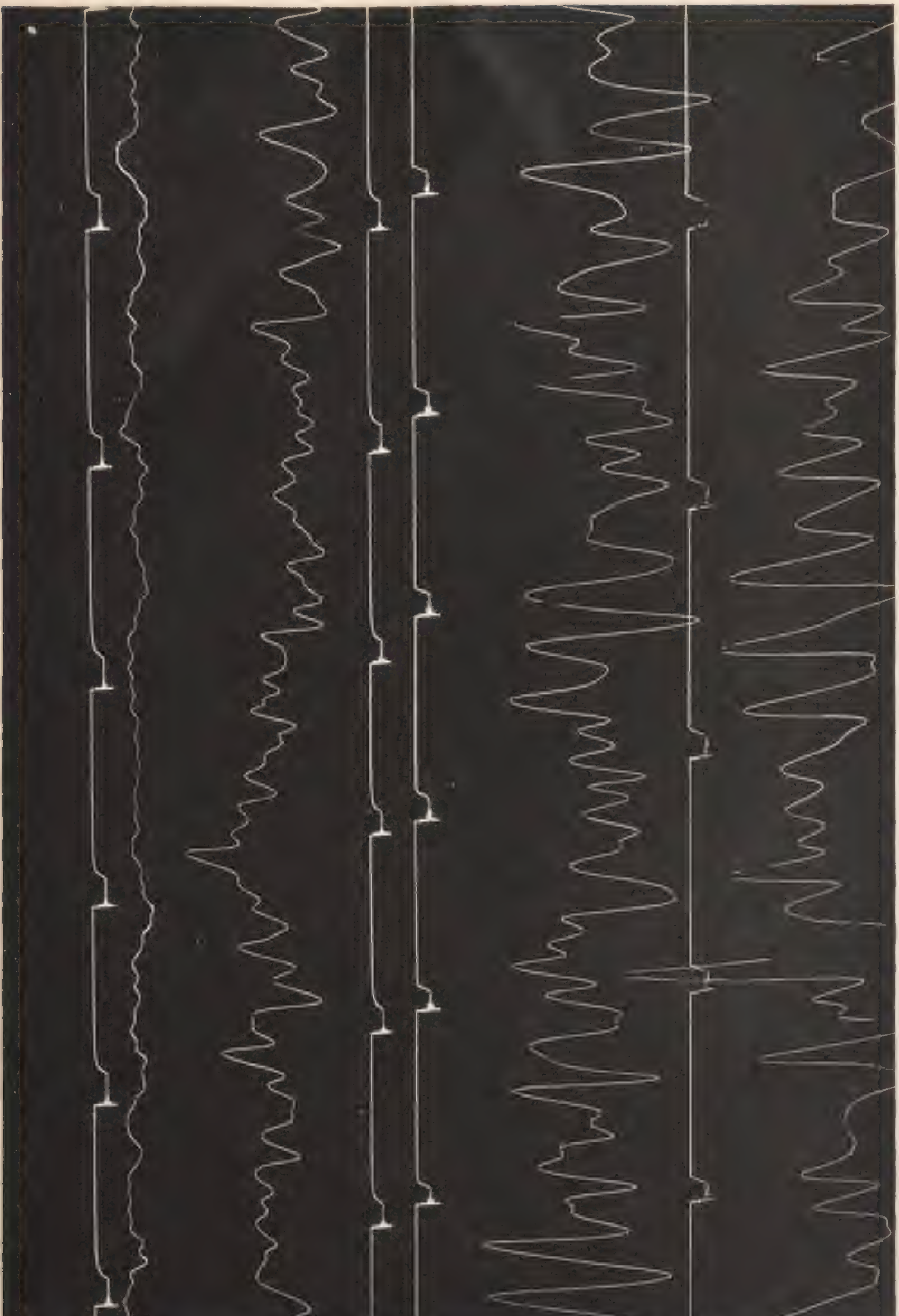
a b c d

TRACING 1.



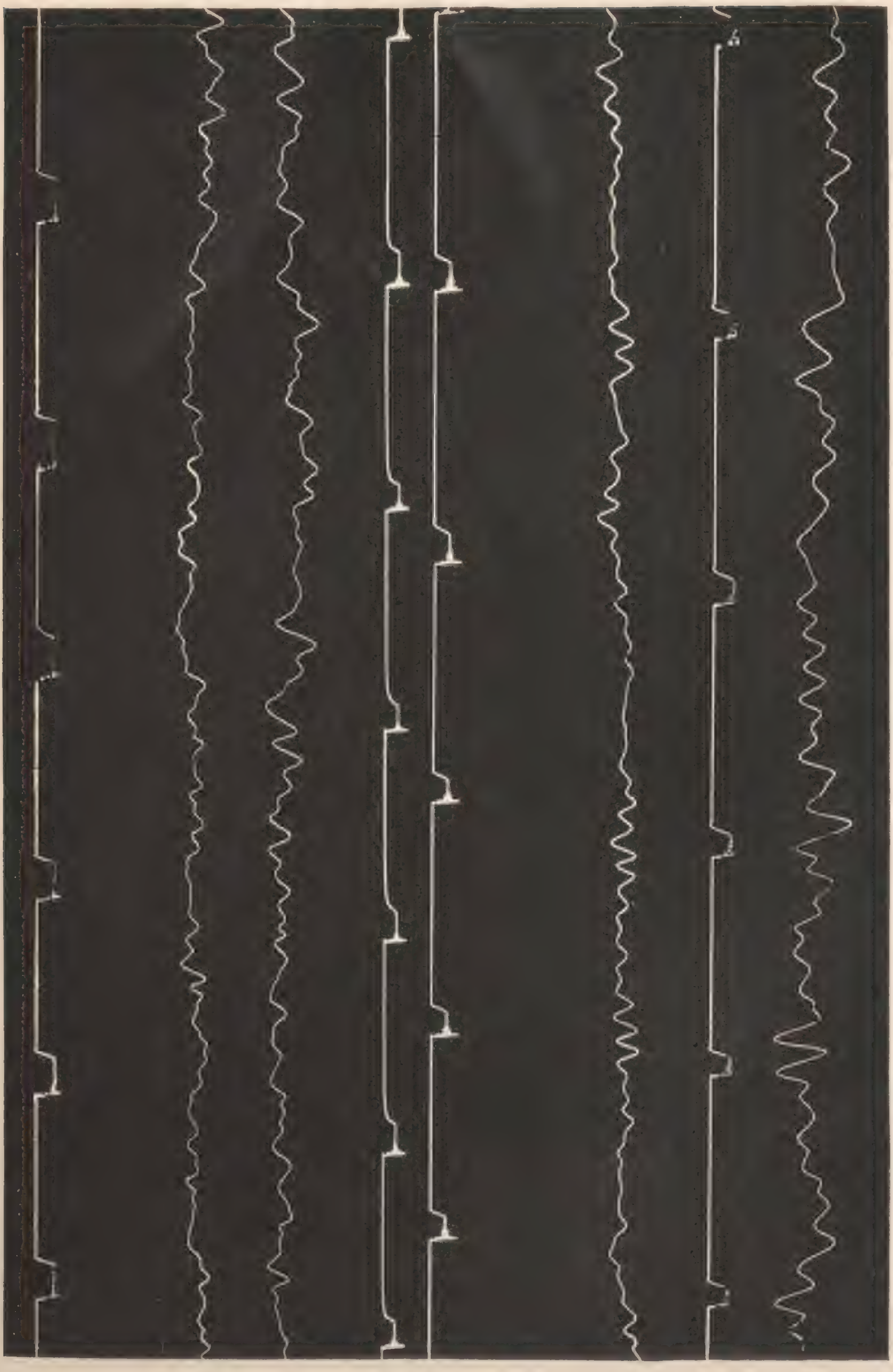
a b c d

TRACING 2.

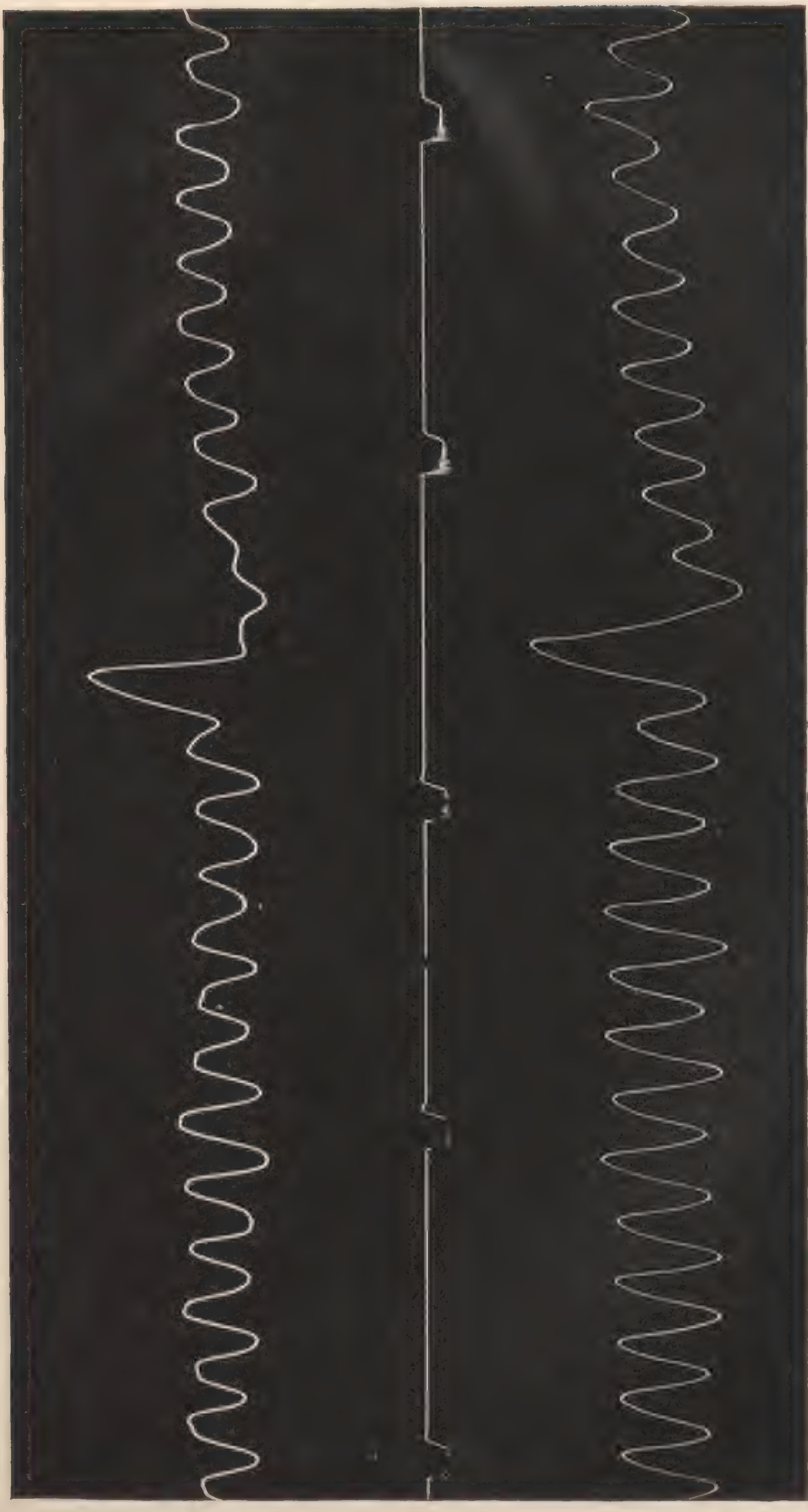


a b c d

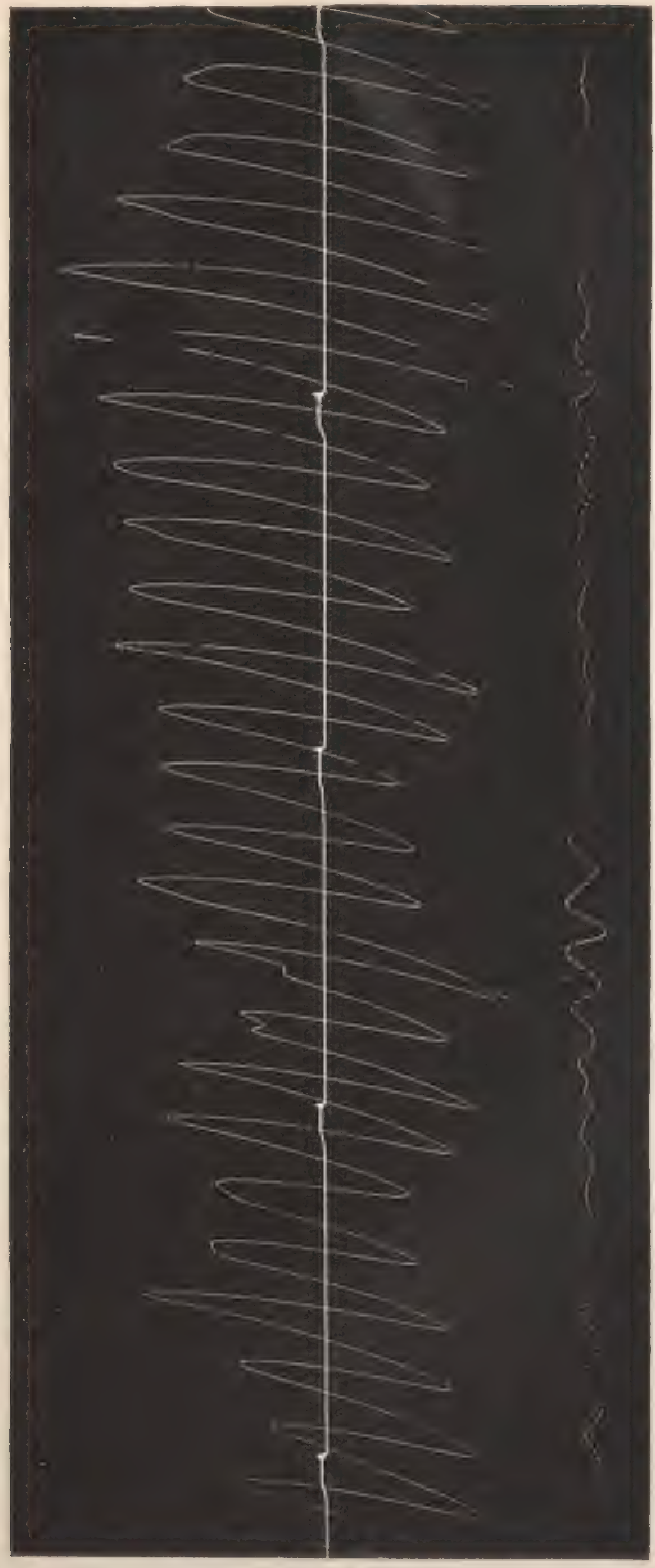
TRACING 3.



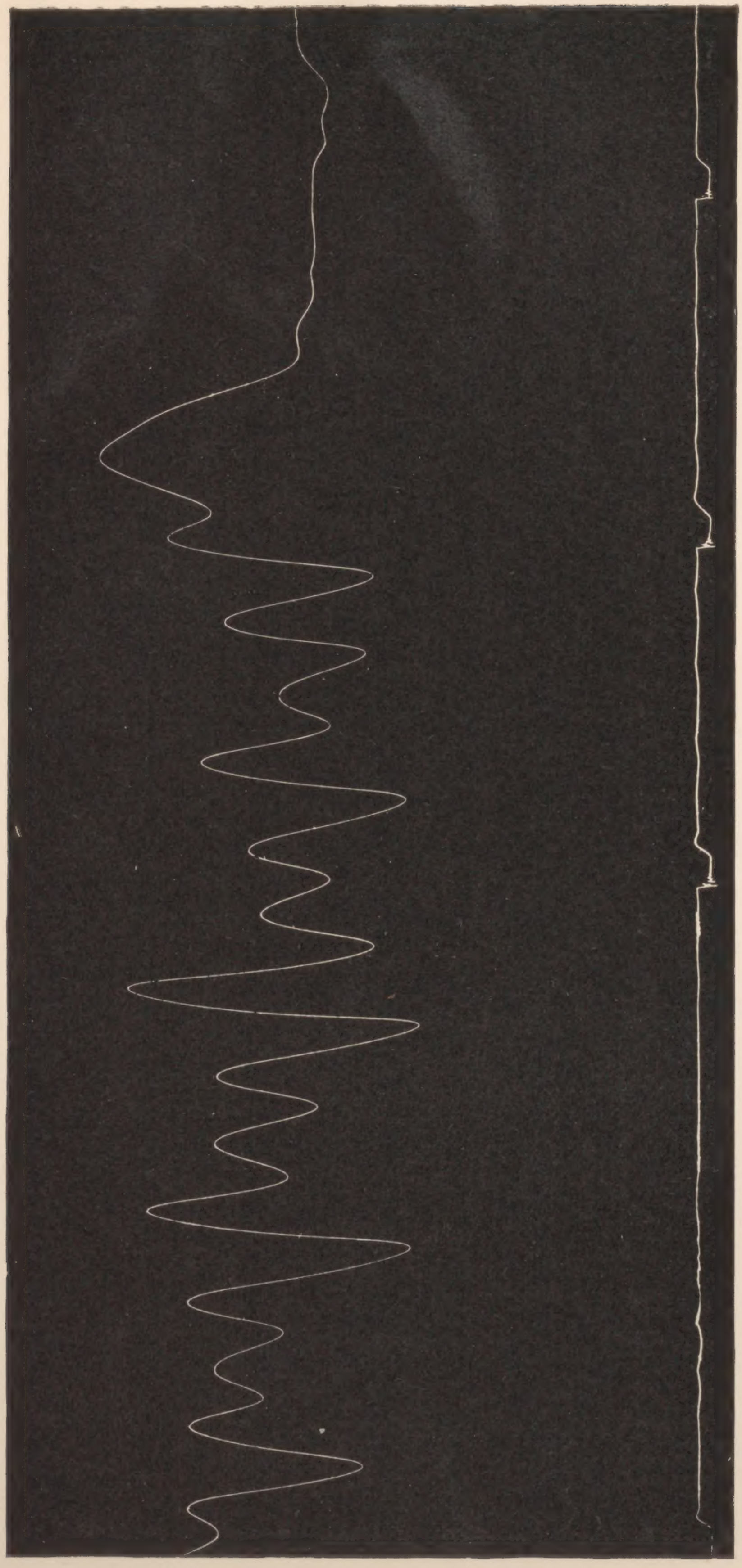
TRACING 4.



TRACING 5.



Tracing 6.



+ FINGER EXTENDED.

TRACING 7.